Remote Sensing of Water Vapour from Ice in the Laboratory

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Introduction

In the frame of the MARVIS (Multidisciplinary Advanced Research Ventures in Space) project called SUBICE, our group develops methods of studying astrophysical ices in laboratory conditions using time-domain THz spectroscopy [1] and passive microwave sensing. The latter concerns studies of the gas evolution into a vacuum arising from the sublimation of icy, porous, dusty media. The primary objective of our work is to resolve the structure and composition of the different materials presented on Solar system bodies (e.g. comets, Europa, Mars) using experiments for future space mission implementation. Here, we present the concept of the experimental setup for the ice sublimation experiments and the analysis of radiometry data using ARTS (Atmospheric Radiative Transfer Simulator) [2].

Experimental setup

- A dedicated vacuum chamber called Weevil (Water Emission of Vapour from Ice in the Laboratory) is being constructed to simulate a water plume in space conditions. The main goal is to avoid any influence of the vacuum chamber on the gas profile.
- A heterodyne radiometer operating primarily at the frequency of 557 GHz (water rotational line) is being developed to investigate the gas temperature, velocity and concentration profiles of ejected water molecules [3].

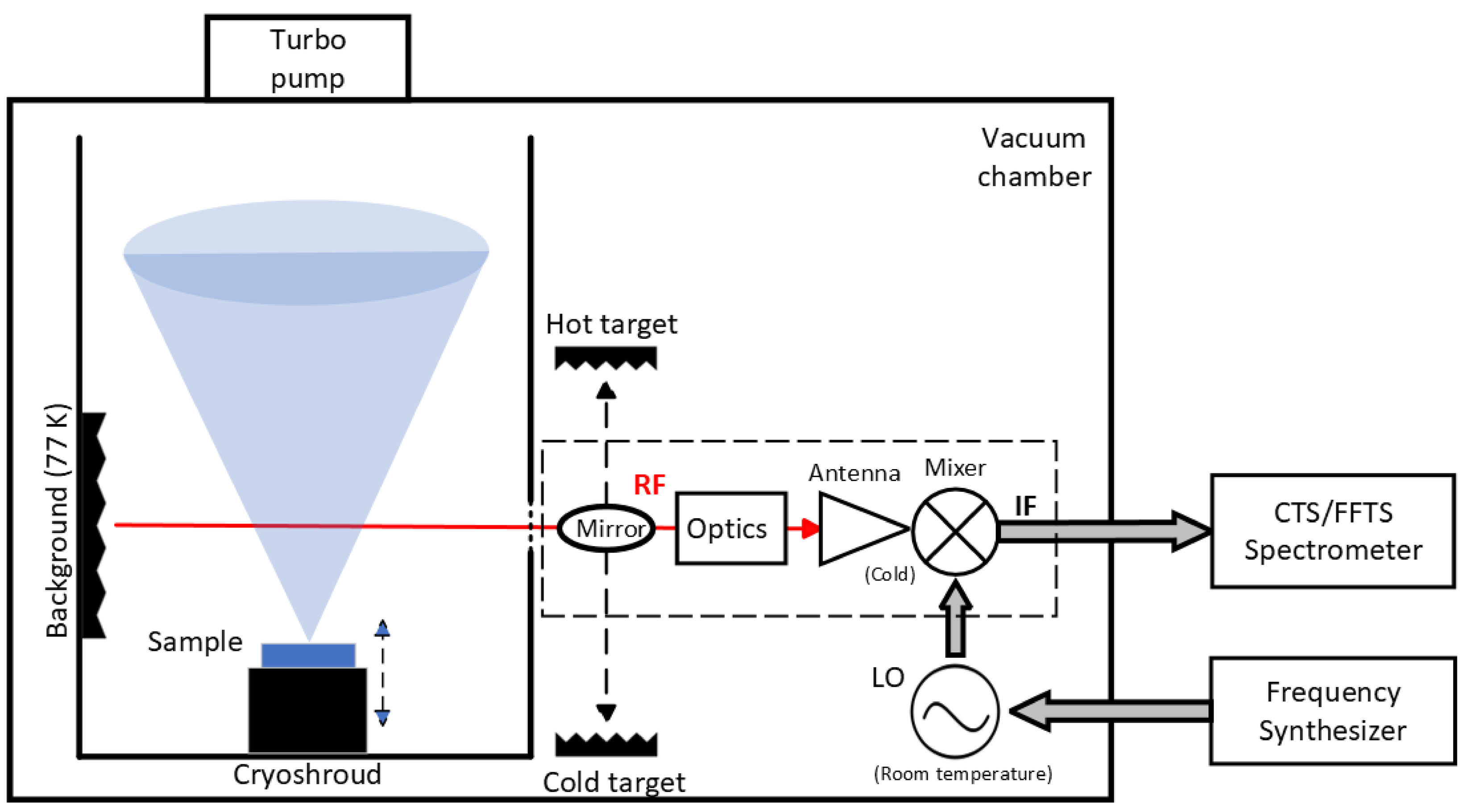

Figure 1. Scheme of the experimental setup (CTS - Chirp Transform Spectrometer, FFTS - Fast Fourier Transform Spectrometer, LO - Local Oscillator)

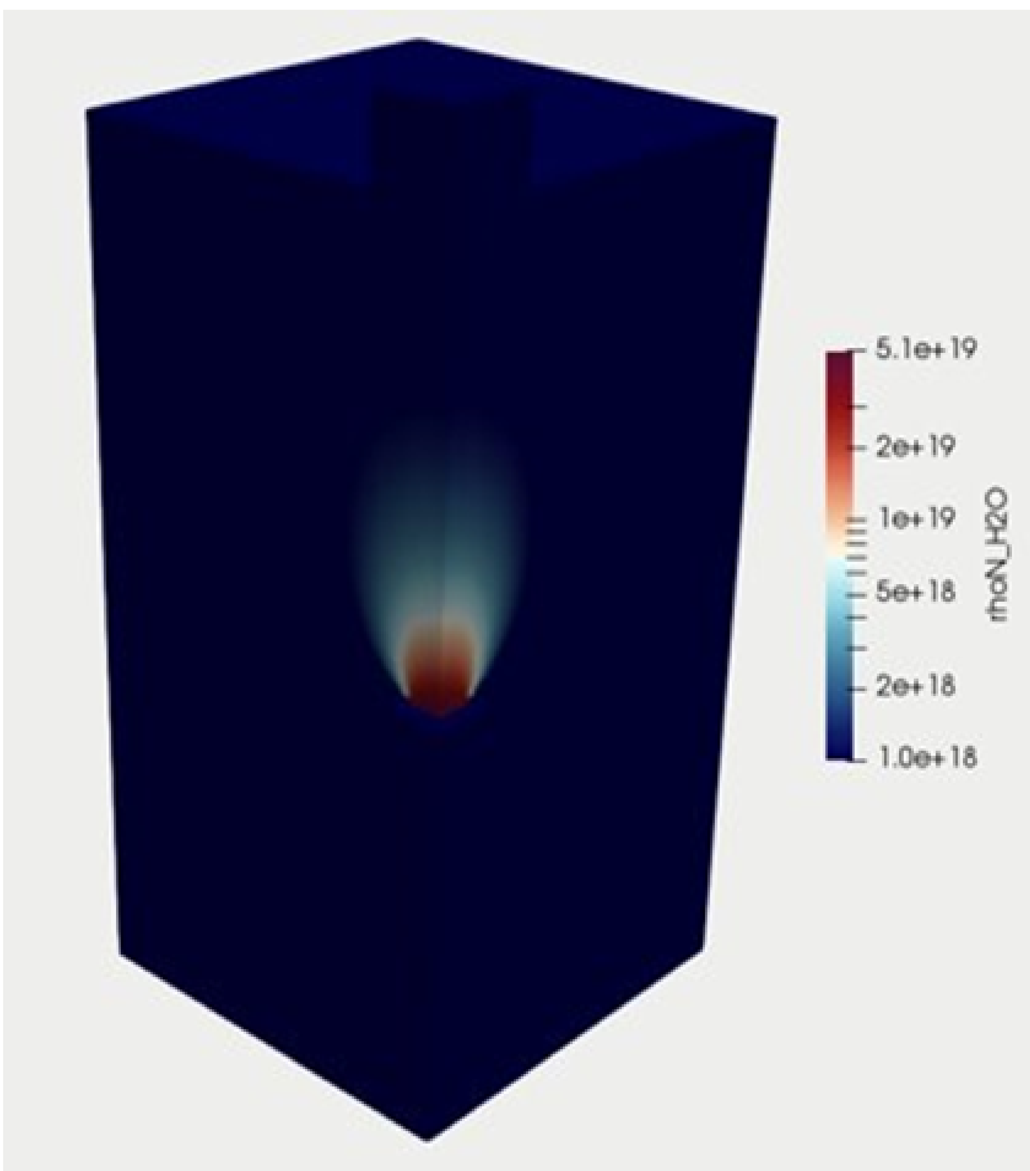

Figure 2. Gas concentration inside a vacuum chamber during sublimation of water ice at the temperature of 200K. The simulation was performed using DSMC under the assumption of complete condensation of gases on the cold walls of a shroud.

Data analysis

- In order to test the experimental concept we simulated brightness temperatures at different altitudes above a sample using DSMC (Direct Simulation Monte Carlo) and ARTS calculations.
- High concentration and temperature of water molecules allow maintenance of LTE for rotational lines. However, the translation temperature of expanding gas with a half-Maxwell velocity distribution would differ from the internal temperature of gas molecules - non-LTE.

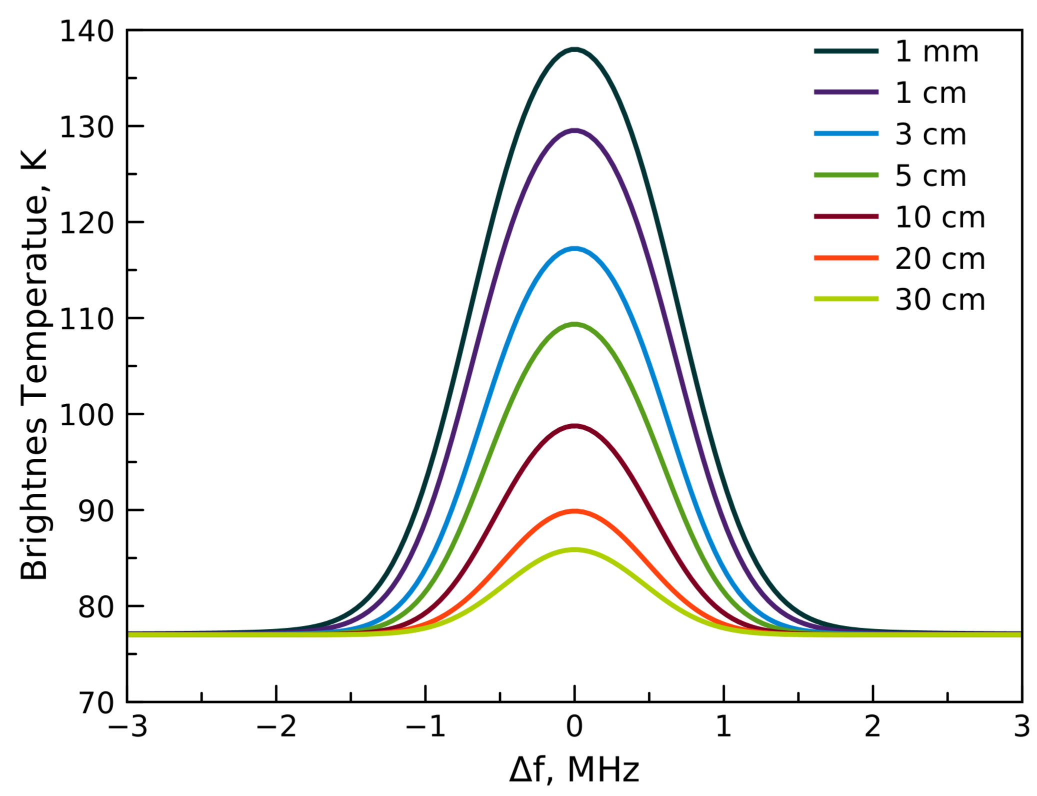

Figure 3. Brightness temperature of water molecules ejected from sublimated ice (10 cm in dameter) at a temperature of 200 K. The calculations were carried out around the 557 GHz emission line and a background temperature of 77 K.

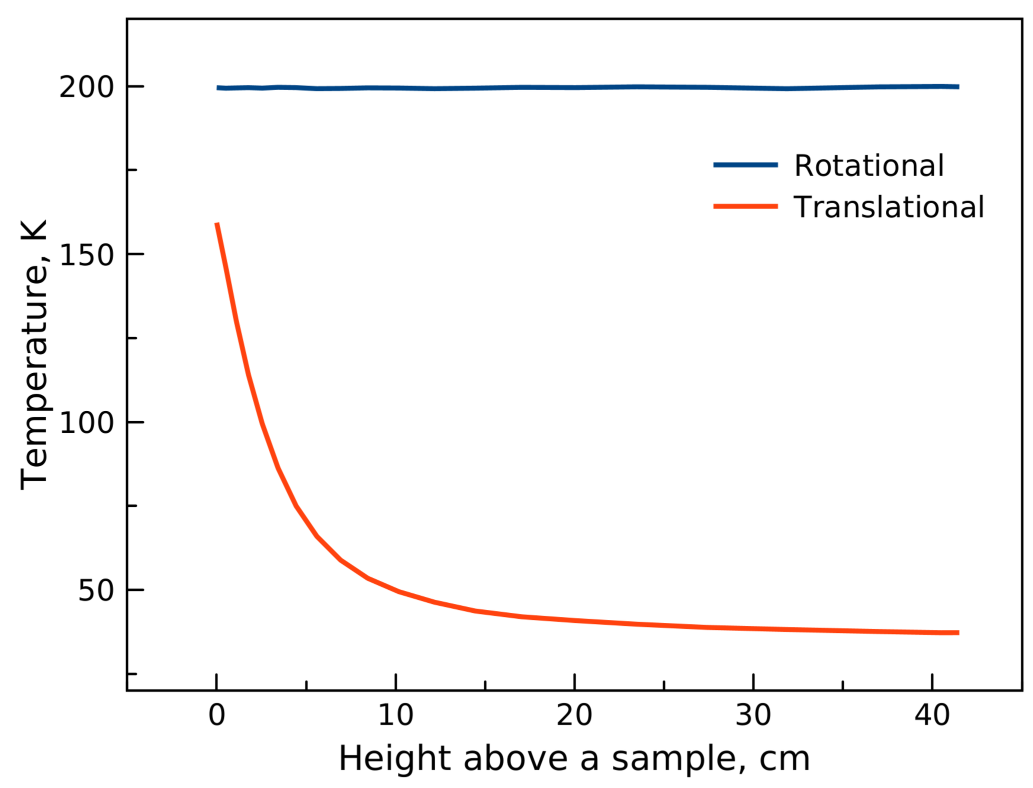

Figure 4. Rotational and translation temperatures of water ice molecules depending on the height above the sublimating water ice sample.

Conclusions

- We present the experimental method of studying internal properties of ices in the Solar system using a microwave remote sensing.
- The experimental setup and measurement equipment (heterodyne radiometer) are under development.
- The combination of gas expansion DSMC simulation and radiative-transfer calculation using ARTS provide valuable information during the designing and the post-processing stages of the experiment.

References:

[1] Stöckli, L. L. et al.,"THz Spectroscopy of Cometary Simulants." IRMMW-THz, 2023.

[2] Buehler, S. A. et al., ARTS, the Atmospheric Radiative Transfer Simulator – version 2.2, the planetary toolbox edition, Geosci. Model Dev., 11, 1537–1556, 2018

[3] Auriacombe, O. et al., TeraHertz desorption emission spectroscopy (THz DES) of space relevant ices, MNRAS, 515, 2, 2698–2709, 2022.

Acknowledgment: This work was supported through a MARVIS programme of the Swiss. Department for Business, Education, and Research (SBFI) called SUBICE. SUBICE is a project of the University of Bern, the University of Applied Sciences and Arts, Western Switzerland (HES-SO), and Thales-Alenia Space Switzerland (TASCH).